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SPEECH COMMAND AUDITORY DISPLAY SYSTEM (SCADS). (U)
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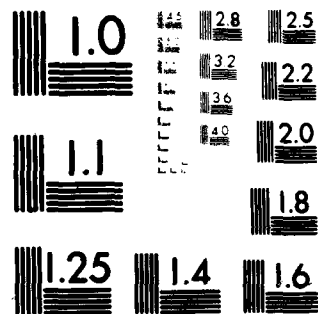
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VOORHEES, MARCHIONDA, & ATCHISON

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SPEECH COMMAND AUDITORY DISPLAY SYSTEM (SCADS) (U)

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INTRODUCTION

The missions of the helicopter, within both the military and the civil sector, have changed rather dramatically over the last 20 years. The military's experience in Southeast Asia during the 1960's demonstrated the wide range of missions that could be accomplished by rotary wing aircraft: fire fighting, heavy lift, and large scale medical evacuations, as well as tactical missions of troop transport and close air support. The post-Vietnam civilian uses for helicopters have duplicated several of the military missions, resulting in an added interest in helicopters in both the military and the civilian sectors. This increased interest has also led to rapid advances in rotorcraft technology. As helicopters have become much more capable, there has been an increasing sophistication in flight controls, power plant systems, and in cockpit displays. This combination of the increase of types of missions and the increase in cockpit sophistication has created a new set of problems. The limiting factor for many types of helicopter missions is now the pilot; and the limitation appears to be specifically related to information transfer. This information transfer is in the form of aircraft status information to the pilot, and information transfer from the pilot back to the aircraft in the form of control manipulations.

One of the most pressing problems within the military helicopter flight procedures is Nap-of-the-Earth flight (NOE). NOE flight occurs at altitudes below the surrounding terrain features and vegetation - so that pilots fly between trees or down a canyon below the level of the walls. NOE flight is performed by a team of two aviators who share the effort. The pilot controls the aircraft and visually interacts with the outside world in order to avoid obstacles. Although he monitors flight information on his instrument panel, this activity is restricted because it diverts his visual attention from the outside scene where the most pressing dangers exist. The co-pilot monitors the position of the vehicle on a map, and provides "look ahead" guidance information to the pilot so that they arrive at their destination. Although pilot and co-pilot may feel apprehensive

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about their inability to monitor systems status information, neither has enough time to look at instruments. This creates considerable anxiety concerning aircraft system status. This anxiety adds to the stresses already present in a dangerous situation. This visual overload problem becomes more severe as the complexity of the cockpit increases. The typical consequences of the visual overload situation is that the pilot slows the helicopter down. When the pilot must look at the panel or manipulate switches on the console, he is not prepared to avoid an obstacle, consequently he tends to slow down. One attempt to minimize visual workload has been to introduce CRT displays and helmet mounted head-up displays to give the pilot aircraft system information. Unfortunately, the addition of more visual information can have a negative effect on the pilot's already overloaded visual system. Making this problem more difficult is the arrangement of flight controls in helicopters - both hands and both feet are necessary to control the aircraft. This makes it difficult to use the multi-function CRT displays which require a large number of key press entries.

There are two major lines of research which are addressing the problem of high visual workload in NOE flight. One is focused on refining the visual information presentation media of aircraft status and navigation data, via CRT, Head-up-Display (HUD) or Helmet-Mounted-Displays (HMD). Although a great deal of effort has been expended in this direction, with some very clever displays as a result, all such displays further increase the already high visual workload of the NOE pilot. The second approach is to explore alternate sense modalities to present the information. The two most widely proposed alternate means of information transfer are tactile and auditory. Tactile displays are currently being studied by Drs. Jagacinski and Gilson at Ohio State University under a grant from the Army Research and Technology Laboratories. Auditory display research, both voice recognition and speech production, is being conducted at the U.S. Army Avionics Research Development Activity, and at our facility, the U.S. Army Aeromechanics Laboratory, in a joint program with NASA.

Our approach within the NASA/Army Helicopter Human Factors Office began with a task simulation of NOE flight. Previous attempts to duplicate the visual elements in a NOE flight scenario through either a terrain board or computer graphics have not been completely successful. As an alternative, we have developed a computer generated maze, which matches as closely as possible the task demands of NOE flight, while presenting a simplified visual display. This task was designed to make it necessary for the subject to be aware of his airspeed, altitude, and torque readings to maximize performance. These three aircraft performance readings were then presented either visually or requested by voice command and presented auditorily via synthesized speech. It was hypothesized that if the visual workload of the task was very high, then trying to gather aircraft performance information visually would result in poorer performance than if the information was available in an auditory mode.



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METHOD

Subjects

Fourteen subjects served as paid volunteers in the study. They were college students recruited from a local university. The age range was from 18 - 31, with a mean age of 22.5 years. There were nine males and five females. All subjects were right handed with normal hearing and vision. None had previous flight experience.

Apparatus

The maze was a computer (PDP 11/70) generated graphic display using an Evans & Sutherland picture system. The task to be performed by the subjects consisted of moving a circular cursor (0.8 cm in diameter) representing a helicopter rotor disk, through mazes of obstacles representing trees. The maze was presented in a stationary "plan" view; that is the subject viewed the obstacles and his helicopter symbol from above. (see Figure 1.) The 49 obstacles were shaped like "plus" signs and were of five sizes (ranging from 1.0 to 0.1 cm). The size of these obstacles varied with the altitude of the helicopter in a ratio of 0.2 cm/20 feet of altitude. The centers of the obstacles were 2.0 cm apart, so that two of the largest trees, located adjoining each other, completely closed the space between them at zero feet of altitude. To move the helicopter through this space the subject had to be at a minimum of 40 feet indicated altitude.

The subject had two controls with which to maneuver the helicopter. The right hand control (representing the cyclic) was a centering joystick which controlled direction and acceleration. The left hand control (representing the collective) was a slide potentiometer which controlled the torque. The PDP 11/70 was programmed with a helicopter model (based on the UH-60 Blackhawk) which controlled the movements of the circular cursor via input from the subject controls. Subjects were located in an IAC sound attenuating chamber.

Experimental Condition

There were three display formats that presented airspeed, altitude, and torque information to the subject.

1. Conventional Dials (CC): Subjects received information from three single needle dials located on a console in front of them and below the level of the viewing screen for the maze. The location of the console was consistent with military cockpit specifications as to distance and viewing angle. Dials were illuminated with indirect lighting, and the numbers were white on a black background. The airspeed and torque gauges had red lines at 75 knots and 42 pounds of torque; the altimeter was not red lined.
2. Head-up-Display (HUD): Ribbon type gauges were drawn by the graphics system on the CRT around the periphery of the maze: (see Figure 1.) the altimeter on the left side, the torque gauge on the

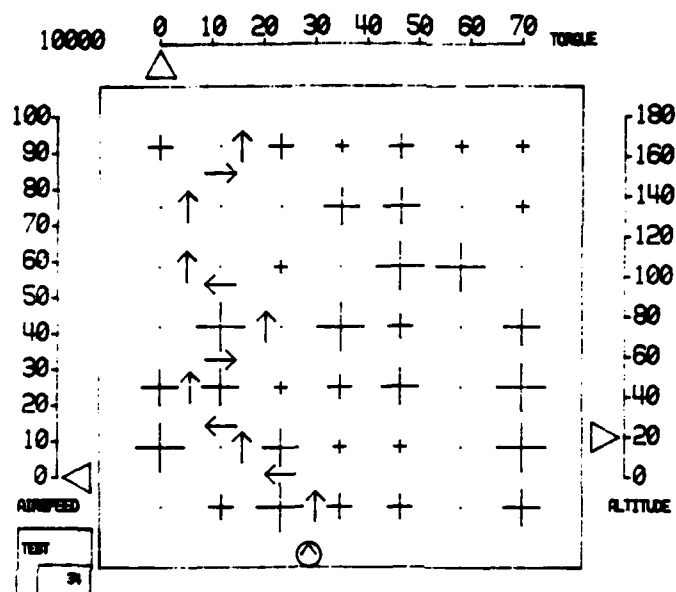


Figure 1 - The maze as displayed on the experimenter's screen showing the path along which the subject maneuvered the helicopter symbol. This maze is shown with the Head-up Display (HUD), the point count (upper left), and all of the direction arrows. The subject's maze displayed only two arrows at a time, for two seconds.

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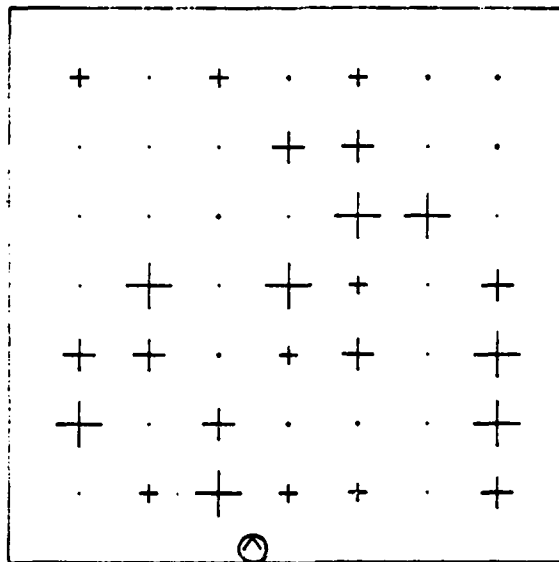


Figure 2 - The maze as displayed on the subject's screen for the conventional dial gauges and the auditory display conditions. The point count is shown in the upper left. In the Head-up Display condition the HUD would appear around the maze as in Figure 1.

top, and the airspeed gauge on the right side. Readings were presented via pointers moving up and down the gauge, which flashed when any of the limits were exceeded.

3. Auditory Display (AF): Subjects received synthesized speech feedback responses to spoken requests for airspeed, altitude, and torque. Spoken requests by the subject were received by an Interstate Electronics Voice Recognizer and interfaced with the PDP 11/70. Instrument readings were computed by the 11/70, and transferred to a SOL microprocessor, the output was given to the subject by a Votrax ML-2 speech synthesizer. There were also unrequested voice warning messages if the subject exceeded parameter limits.

During all display conditions there was a background cockpit noise tape playing at 90 db(A). The subjects wore a headset which had a 40 - 45 db attenuation. All speech responses, as well as communications with the experimenter were via the headset.

The subject's performance was monitored on a second screen located outside of the IAC chamber at the experimenter's station. The experimenter also had a video monitor which allowed for the monitoring of eye movements.

Procedures

Fifteen subjects were selected on the basis of preliminary screening with a critical tracking task. One dropped out after two weeks so the remaining fourteen were used. Subjects were instructed to maneuver their helicopter through the maze as fast as possible while staying as low as possible. The subjects were required to follow a path through the maze. This path was made up of arrows which flashed on between the trees showing the next two turns to take. (see Figure 2.) The arrows were only illuminated for two seconds, and if the subject missed seeing the arrows he/she had to say the word "direction" into the voice recognizer which illuminated the arrows. If the subject did not pass over each correct space the maze would not reset and the subject had to return to the place where he/she deviated from the path and retrace that portion of the maze. Subject's current score (out of a possible total of 10,000 per maze) was displayed in the upper left corner of the subject screen as continuous feedback. After a subject completed a maze, the helicopter was automatically reset back to the bottom of the screen and a new maze displayed. Each subject performed one session per week; a session consisted of 20 mazes for the first two weeks and 30 mazes for the third and fourth weeks. All runs during this training phase were with conventional dial gauges. At the end of the fourth week, the fourteen subjects were formed into three matched groups based on their scores. One group (n=4) remained on dial gauges (CC), one group (n=5) shifted to a Head-up-Display (HUD), and the remainder (n=5) now received auditory feedback (AF) with no visual instrument information. The experimental display phase lasted three weeks, with 30, 35, and 35 mazes on weeks 5, 6, and 7 respectively. All subjects received the same mazes (each of which was different) in the same order during a

session. At the end of week 7 the HUD and AF groups transitioned back to the conventional dial gauges. All three groups then completed an additional three sessions consisting of 30, 35, and 35 mazes on weeks 8, 9, and 10 respectively. Average session length decreased from two hours to one hour per session from the first to the sixth week as the subject's performance improved.

In the conditions where subjects were using the conventional dial gauges, an experimenter watched each subject's face on a closed circuit monitor, and recorded eye movements to the gauges by actuating a button connected to the PDP 11/70. This allowed the experimenter during subsequent data analysis to determine at what point in a maze the subject looked down at the gauges, and for how long.

RESULTS

A scoring system was developed whereby the subject was penalized by having points deducted for various events from an initial total of 10,000 points at the start of each maze. Penalties were assessed for the following: (1) length of time in the maze; (2) passing between two trees at higher than the minimum altitude necessary; (3) hitting a tree; (4) flying off course; (5) asking for "direction"; (6) hitting the ground while moving forward; and (7) exceeding limitations in airspeed, altitude, or torque. Subjects were debriefed at the end of each session as to how they had lost points.

The total number of points lost per maze per subject per group were log transformed and subjected to analysis of variance for week 4 (end of training phase), week 7 (end of test phase), and week 10 (end of return to dial gauges). The results for week 7 are presented in Table 1. At week 7 the ANOVA showed a significant difference ($p .01$) between groups. A Scheffe test for multiple comparisons was run on the week 7 data (Table 2).

Analysis of Variance Summary Table

Source	SS	df	MS	F
Between Groups	.000946	2	.000473	4.637*
Within Groups	.049709	487	.000102	

* $p < .01$

Table 1. - ANOVA for scores from the 7th week of testing.
(scores were log transformed)

Scheffe Multiple Comparison

	CC	HUD	AF
	139.276	139.321	139.389
CC 139.276	-	.0450*	.1130*
HUD 139.321		-	.0680*
AF 139.389			-

$p < .01$

$CR_s = .0247$

Table 2. - Comparison of the three experimental groups on 7th week performance. CC-conventional dial gauges, HUD-head-up display, AF-auditory feedback.

Results of this test showed a significant improvement in performance ($p < .001$) in the HUD group compared to the control group (CC) and in the auditory feedback (AF) over both the control group (CC) and the HUD group. The week 10 data showed the AF and HUD groups performance returning to the control level (although the AF group's performance was still significantly better).

DISCUSSION

This research was undertaken to answer two basic questions. First, could a relatively simple graphics task simulation be developed to investigate NOE flight problems? Second, would the use of a synthetic speech display of aircraft flight parameters be as effective as conventional dial gauges of a head-up-display in conveying information to a subject flying an NOE simulation?

In the first area, the task development, we believe that the "plan" view maze task has shown itself to be sensitive to various manipulations such as type of information display. This type of task similarity to NOE flight, as opposed to visual similarity is encouraging, particularly for small scale laboratory investigations. It remains to be determined, of course, if trained helicopter pilots would respond in a similar manner to non-pilot subjects. This type of task may prove very useful in examining an issue such as side arm controller vs. conventional controls.

In the second area, that of the use of speech feedback for instrument information, the results are clearer. Performance (as measured by the previously described metric) significantly improved when the visual workload of gathering instrument information was off-loaded to the auditory channel. The significant improvement in performance for the AF group over the HUD is particularly interesting. Several investigators have advocated

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the use of HUDs to replace conventional dial gauges to eliminate the pilot's need to look at the instrument panel. Our results bear out their contention that this system is an improvement over dials, but we also find that the use of an auditory display of instrument information is significantly better than the HUD or the dials. With the advent of various night vision systems, and the possibility of a single pilot scout helicopter on the horizon, speech technology should be considered as a major candidate for information transfer systems.

The development of this type of laboratory task for task simulation of a procedure like NOE flight could be very useful in the area of standardization. One of the major problems that has consistently recurred in human performance testing in aviation simulation has been the problem of different task demands imposed by the testing procedures. The area of workload measurement is an example of how this procedure difference has frustrated attempts to understand the phenomena of concern. The use of an easily transferred task such as the maze task used in this research, offers an inexpensive simulation that can be used for a wide variety of testing, within a standardized framework.

